

Diagnostics for the Measurement of Particulate Matter Emissions from Reciprocating Engines

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ABSTRACT

Since 1988, particulate matter emission regulations in the US for heavy-duty diesel engines have mandated a reduction from 0.6 g/bhp-hr to the current level of 0.1 g/bhp-hr. As large an improvement as this has been, however, looming in the not-to-distant future is a requirement for an additional order-of-magnitude reduction, to 0.01 g/bhp-hr by 2007, as illustrated in Fig. 1. It will take a major effort by industry to reach this target, and it will most likely require the use of a particulate trap. But this large reduction in total particulate mass will also create a new problem - how to measure it. The current gravimetric procedure of weighing a sample collected on filter paper will be impractical because of the long time required to collect sufficient mass to be detectable. This problem of measurement sensitivity is compounded by the fact that the size of particles emitted by contemporary engines is far smaller than that of engines of 1988. This is why particulate matter emissions are no longer visible. However, achievement of this reduction in size came at the cost of a tradeoff with the number of particles emitted, which has increased by several orders of magnitude and poses a potential health concern. These new issues of size and number may prove to be as important, or even more so, than particulate mass, raising questions about whether “what” is regulated may also change in the future. Compounding this problem are newly raised issues regarding whether the nanoparticles observed in a dilution tunnel are representative of tailpipe exhaust dilution by the atmosphere. In order for regulators to address these issues, improved measurement techniques are needed now, to provide a better understanding of the importance of size and number on environmental and health issues.

It is also important to note that beginning in 2004, gasoline fueled vehicles will be required meet the same regulations as light-duty diesel vehicles. Current port fuel-injected gasoline engines will have no difficulty meeting the 2004 levels, but it is much less certain for gasoline direct-injection engines, or for either type in 2007. Gasoline engines, in general, are known to emit particulates during cold start, and gasoline direct-injection engines have been shown to produce measurable PM during lean burn operation.

Industry will also need new diagnostic tools to help them meet the 2007 particulate matter requirements. As engine emissions continue to become cleaner due to improvements in the combustion process, the contribution from engine transients will play an ever-increasing role. Only a few of the particulate measurement instruments currently in use respond in real time, and it is doubtful that these will have the sensitivity required for the new regulations.

In this paper, I review the diagnostic tools for particulate matter measurement that are currently available commercially, looking first at those that measure total mass, volume, area, or number, and then those that can characterize particles based on size. I next describe some new techniques that are currently only being used in research, and some that have yet to be demonstrated. I conclude with my recommendations for the instruments most suitable for use today, and my projections for the new techniques that show the most promise.

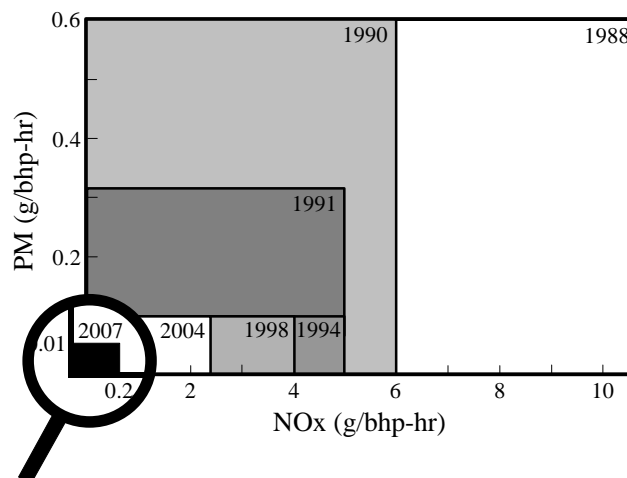


Fig. 1 Evolution of US heavy-duty diesel engine emission regulations.